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Digital-Based Hybrid Learning in Mathematics

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Abstract. The integration of traditional face-to-face instruction with digital-based learning platforms in Mathematics remains underexplored, particularly in developing high-impact learning outcomes. This study assessed the effectiveness of digital-based hybrid learning in Mathematics through the development and validation of a mobile application, Smartmathics. Utilizing a Research and Development (R&D) approach and the ADDIE model, the study employed a Solomon four-group design with 120 learners. Results indicate Smartmathics as highly valid and highly acceptable, significantly improving academic performance compared to traditional methods. Notably, experimental groups exposed to digital-based hybrid learning demonstrated substantial progress, suggesting its potential to enhance learning outcomes and bridge understanding gaps. This innovative approach underscores the transformative power of technology in education, offering dynamic platforms for deeper comprehension and higher achievement levels in Mathematics.

Keywords: Digital-based hybrid learning; Mobile learning application; Smartmathics; R&D approach.

1.0 Introduction

Learning Mathematics is described as an active process of knowledge acquired directly and indirectly by education and experience. The average Math learner needs training and guidance, reducing cognitive information volume to understand and optimize the storage of new concepts. As Mathematics teaching practices improve, learners are expected to be more active and engaged in their learning, leading to improved performance. However, poor national and international testing performance, high dropout rates, unpreparedness, and other pressing education issues remain significant problems despite massive efforts to reallocate approaches to excellence and equity (Swofe-Farr, 2021).

Recently, there has been a growing concern about the increasing number of underachieving learners in schools in the Philippines. According to Bringula et al. (2021), a learner's underachievement in Mathematics results from various reasons, including a lack of motivation for learning, cultural deprivation, socioeconomic disadvantage, or unpleasant learning experiences. The 2018 PISA result also revealed that the Philippines received a below-average score in Mathematics. The Philippines' score in Mathematics was significantly lower than the average score of the OECD and lower than that of other ASEAN countries participating in PISA 2018 (PISA 2018, National Report Philippines). The result of the national assessment was also observed in the 2018 National Achievement Test that measured 21st century skills, which were Problem Solving, Critical Thinking, and Information Literacy across five (5) subject areas. Mathematics recorded the lowest performance (DepEd Memo: 2018 NAT Results and Analysis, 2019). Additionally, in the 2019 Trends in International Mathematics and Science Study (TIMSS), Filipino students ranked among the lowest in both mathematics and science among 58 participating countries. According to Scott et al. (2018), the problem is that Mathematics educators do not know how and to what extent literacy in Mathematics can be used. School systems across the country are focused on improving Mathematics achievement, but academic achievement in public schools remains a significant problem.

The enduring repercussions of COVID-19 on society, particularly in education, persist despite vaccination efforts, perpetuating ongoing anxieties about health and safety. These lingering effects can indeed impact students' attendance and participation in school. Don Eulogio de Guzman Memorial National High School encourages students to stay home when they exhibit even mild symptoms of illness. These policies are intended to prevent the potential spread of any contagious illness, but they can also lead to more frequent absences for minor health issues. However, the experience of distance learning during the pandemic has demonstrated that students can continue their education from the comfort of their own homes.

Additionally, DepEd had authorized school principals and administrators to suspend face-to-face classes and transition to alternative methods of instruction due to extreme heat. DepEd allowed schools to shift to alternative delivery modes during extreme weather conditions, including days when high temperatures affected the learning environment. Teachers sometimes effect changes in education through the implementation of new ideas, and at other times, extraordinary circumstances force them to adjust their educational approaches. Although we live in a digital age, the limited use of technology in education and teachers' insufficient experience with online or hybrid learning and teaching approaches resulted in being unprepared for education. To minimize learning disruptions, class suspensions during disasters will only affect the face-to-face component, with students expected to continue their education at home, according to DepEd Order No. 22, s. According to the Implementing Guidelines on the School Calendar and Activities for the School Year 2023–2024, in-person learning shall remain the primary learning modality in all schools. However, schools shall automatically implement a blended learning delivery modality in the event of the suspension or cancellation of in-person classes due to natural or human-induced disasters, calamities, or other disruptions to in-person classes.

Hybrid learning as one learning approach is a model that encompasses both teaching and learning, providing a framework for academic practice. It is characterized by a combination of face-to-face and technology-mediated activities (Linder, 2017). The hybrid approach offers flexibility, enabling students to customize their learning paths and engage with course content at their own pace. This model not only accommodates diverse learning styles but also provides opportunities for increased student engagement, personalized learning, and the development of digital literacy skills. Moreover, digital devices have gained widespread acceptance in education over the past few years. Smart devices, such as mobile phones and tablets, along with their accompanying applications (apps), are an integral part of young children's daily lives. These tools enable children to leverage new learning platforms and acquire knowledge effectively through activities related to their immediate interests and real-life scenarios within learning domains, such as mathematics (Papadakis, 2021). The evolution of educational technology necessitates the development of new mathematics tools to meet diverse learning needs, enhance interactivity, and align with modern curriculum standards, ensuring engaging and compelling learning experiences.

For these reasons, the researcher developed a mobile application to teach mathematics, aiming to foster an understanding of a transformational reform effort that benefits teachers, learners, and the education system as a whole. Developing a mobile application as a streamlined solution for digital-based hybrid learning is imperative, especially during unforeseen events that lead to the suspension of classes.

2.0 Methodology

2.1 Research Design

This study employed the Research and Development (R&D) method, specifically the descriptive–developmental design. Research and Development is a dual-purpose design process aiming to create a product while simultaneously evaluating its effectiveness through iterative refinement stages (Mufadhol, 2017). The descriptive nature of this study lies in its analysis of the validity and acceptability of a mobile application designed to enhance digital-based hybrid learning in Mathematics. In this study, the researcher utilized the ADDIE model.

Analysis Phase. This study focused on integrating eleven (11) most essential learning competencies of Grade 9 Mathematics, as guided by the budget of work provided by La Union Schools Division Office, into a mobile application-based learning platform, facilitating interactive digital content delivery, student assessment, and self-learning modules, thereby enhancing pedagogical strategies for adequate mastery of math concepts.

Design Phase. The device aspect considers the physical, technical, and functional characteristics of a mobile device, as well as how mobile devices enable communication and collaboration among multiple individuals and systems. This was also designed for Android with careful consideration of specific criteria and features. The device's physical design prioritizes one-hand operability while offering a wide screen for an enriched viewing experience. Input options include a user-friendly touchscreen and a keyboard screen to accommodate diverse preferences. Output features, including a speaker, support audio-based learning. The device ensures at least 500 MB of storage for seamless file access, backed by a 1 GB RAM processor for smooth performance. Networking capabilities, such as Wi-Fi, enable versatile connectivity, which is essential for accessing online content. Integration with collaboration tools, such as calendars and score retrieval, enhances scheduling and organization for both students and educators. The mobile application is designed to enhance student learning and engagement by providing a suite of features, including user account management, offline access to learning materials, diverse assessment options with instant feedback, interactive games, and score sharing with teachers for comprehensive progress tracking. For teachers, the app offers tools for managing virtual classrooms, including account creation, student enrollment, attendance tracking, and analysis of student scores across different assessments, thereby facilitating efficient classroom management and academic monitoring. Figure 1 depicts a use case diagram illustrating interactions between users (actors) and the system, particularly emphasizing the diverse functionalities available to students interacting with the application through various use cases.

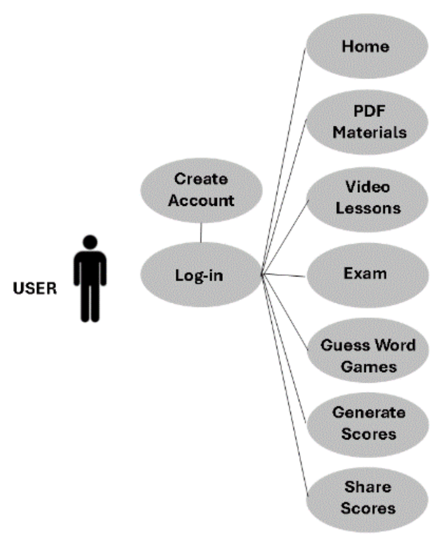

Figure 1. *Use Case Diagram*

Development Phase. The purpose of this phase is to develop a digital-based hybrid learning approach in mathematics through a mobile application. This phase involves operating the MELC-based self-learning modules using various software, hardware, and supporting documents. The development of the Android application relied on Android Studio as the primary IDE, utilizing Java as the programming language to ensure reliability and efficiency. Object-oriented programming principles were applied to enhance code organization and maintainability. XML was used for UI design, while an SQLite database managed and secured user data. The app targeted API 31 for compatibility with the latest Android features and adhered to Material Design principles for a modern interface. Responsive layouts ensured adaptability across devices, while security measures included encryption and user authentication. Canva was utilized to create visually appealing graphics and images, thereby enhancing the overall aesthetic and user experience.

Implementation Phase. Learners used the developed digital-based hybrid learning for 8 weeks during the second quarter period. The validated mobile application as digital-based hybrid learning was given to the students for experimentation. Throughout the implementation phase, strict adherence to the Data Privacy Act of 2012 (Republic Act No. 10173) was ensured to protect the privacy and confidentiality of the students' data. The study safeguarded the privacy rights of the students and protected their personal information throughout the implementation of the digital-based hybrid learning tool. Figure 2 provides a structured framework that utilizes the 7E Model for incorporating digital-based hybrid learning through a mobile application, while still allowing for face-to-face interaction and engagement.

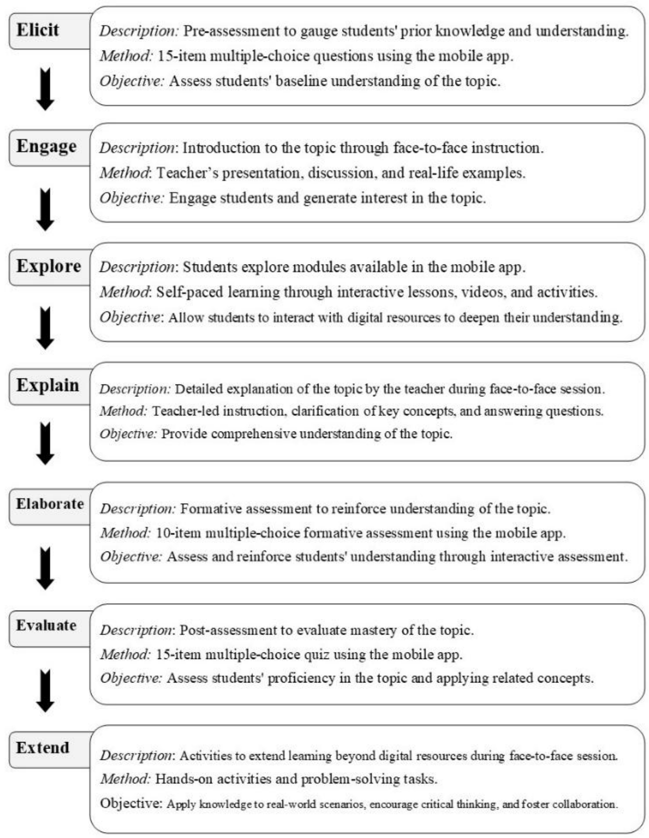

Figure 2. *The 7E Model Structured Framework of Digital-Based Hybrid Learning*

Evaluation Phase. This phase measured the effectiveness and efficiency of the instruction. Following the implementation of the approach, a post-test was administered to the students. Moreover, the researcher utilized the Solomon four-group design, an experimental method involving random assignment to four groups differing in treatment receipt and outcome measurement frequency, to investigate the study's objectives. (Braver, 1988).

Group	Pre-test	Treatment	Post-test
1	O_1	Experimental Group	O_2
2	O_3	Control Group	O_4
3	-	Experimental Group	O_5
4	-	Control Group	O_6

2.2 Research Participants

The participants of this study were 120 learners from a national high school, with 30 participants in each class. All groups demonstrated a high degree of comparability based on their similar mean first-quarter grades. G1 and G3 were assigned as experimental groups, while G2 and G4 were assigned as control groups. Six experts in Mathematics and five IT experts were selected to validate the developed mobile application for digital-based hybrid learning in mathematics, ensuring a robust evaluation process where validators possess strong mathematical foundations and proficiency in integrating technological tools into educational contexts, thereby guaranteeing the application's validity and effectiveness. Additionally, thirty-six (36) students participated in the validation process to assess the acceptability of the mobile application. As the intended end users, these students provided crucial feedback. Their insights were instrumental in determining whether the application met the needs of its target audience and identifying areas for improvement.

2.3 Research Instrument

A very highly valid instrument with a content validity index of 1.0 with five (5)-a five-point Likert scale was utilized in determining the level of validity in terms of content and technical quality and the level of acceptability in terms of clarity, usefulness, language style, and illustrations of the digital-based learning in mathematics. The researcher utilized a highly valid teacher-made pretest and posttest to collect data on their academic performance. The test allowed the researcher to assess the participant's academic performance in the selected most essential learning competencies in Mathematics. Specifically, the test content focused on key mathematical concepts, particularly variation, exponents, and radicals. These areas were selected because they are fundamental to understanding higher-level mathematical reasoning and problem-solving, aligning with the subject's curriculum standards. The reliability of the pretest and posttest was piloted in Luna National High School. Using the split-half method, the computed correlation coefficient was 0.81, indicating high reliability. Additionally, the computed Spearman-Brown correction was 0.89, further enhancing the instrument's reliability.

2.4 Data Gathering Procedure

During the study, the researcher administered the pre-test to the participants. After this, participants received a learning approach using digital-based hybrid learning in the two groups and a traditional approach in the other groups. Participants were then asked to complete the post-test to assess their knowledge about the topic and academic level of performance after implementing the learning approach. To determine the validity and acceptability of the mobile application, the results were tabulated using a median. The results were tabulated using the mean, percentage score, and standard deviation to analyze the learners' academic performance based on the scores of the pretest and posttest. To answer the research question about the significant difference in the pre-test and post-test scores of the learners, the results will be analyzed using a z-test and ANOVA with a Post-Hoc Tukey HSD Test. Z-test was used to test the difference between pretest and post-test scores for each group individually. ANOVA was applied to see if there were any significant differences between the post-test scores of the four different groups. If ANOVA revealed significant differences, the Post-Hoc Tukey HSD Test was conducted to pinpoint precisely which groups differed from each other.

2.5 Ethical Considerations

This research study followed ethical guidelines. The responses and participation of individuals were entirely voluntary, with participants being fully informed of their right to withdraw at any time without facing any negative consequences.

3.0 Results and Discussion

3.1 Development of Mobile Application "Smartmathics"

Table 1 shows the features of the developed mobile application, Smartmathics – the student, teacher, and technology features.

Table 1. *Features of Smartmathics*

Features	Key Features Description
Student	User Registration, Login, Forgot Password, Log Out, PDF and Video Learning Materials, Exam, Guessing Game, Share Quiz
Teacher	Teacher Login, Code Authentication, Teacher Profile, Classroom Management, Receive Student Scores, Log Out
Technology	Android Studio, Java Programming Language, Object-Oriented Programming, XML (Extensible Markup Language), SQLite Database, Minimum 450 DPI, Responsive Layouts, Canva

The successful development of Smartmathics (a mobile application combining smartphone technology with mathematics) represents a significant advancement in education technology, particularly in the context of hybrid learning in Mathematics 9. The development of Smartmathics was driven by a commitment to addressing the evolving needs of mathematics education in the digital era. Smartmathics was crafted as a vision for a mobile application that would seamlessly blend traditional classroom instruction with innovative digital resources. The development process commenced with extensive research aimed at identifying key challenges in mathematics education and exploring existing digital solutions. Collaborating with a skilled IT developer and designer, the researcher translated this vision into reality, iteratively refining and enhancing the features of Smartmathics. Similarly, this platform aims to leverage the advantages of mobile devices to enhance math teaching for students (Alkhateeb, 2019) by accommodating various learning styles, fostering engagement, and facilitating conceptual understanding (El-Sabagh, 2021).

In alignment with pedagogical goals and instructional objectives, Smartmathics focuses on empowering students to master the MELCs of Grade 9 Mathematics. The platform incorporates self-learning modules (SLMs), ensuring alignment with MELCs and promoting mastery-based learning. By integrating SLMs, Smartmathics facilitates self-paced learning and accommodates divergent learning styles. Furthermore, the platform complements traditional teaching methods by providing supplemental learning resources and assessment tools. Smartmathics is a comprehensive platform designed for both students and teachers, offering secure login, personalized learning resources, and efficient database management, with students benefiting from interactive tools and collaboration features. In contrast, teachers gain access to classroom management tools, all built using Android Studio, Java, XML, SQLite, and Canva, featuring a color scheme symbolic of the Grade 9 curriculum and the researcher's personal touch. A 450 DPI (dot per inch) ensures sharp and clear images, enhancing the visual quality of the platform's interface, which is crucial for both students and teachers. Responsive layouts enable the platform to automatically adjust its design across various devices, providing an optimized experience on smartphones, tablets, and other devices. Meanwhile, OOP (object-oriented programming) structures the software around objects, making it easier to manage and expand features like student profiles. Together, these concepts ensure that Smartmathics is visually appealing, adaptable, and maintainable, delivering a seamless and efficient experience. Figure 3 presents the interface of the mobile application catering to student learning, including user account management, access to PDF modules, and assessments.

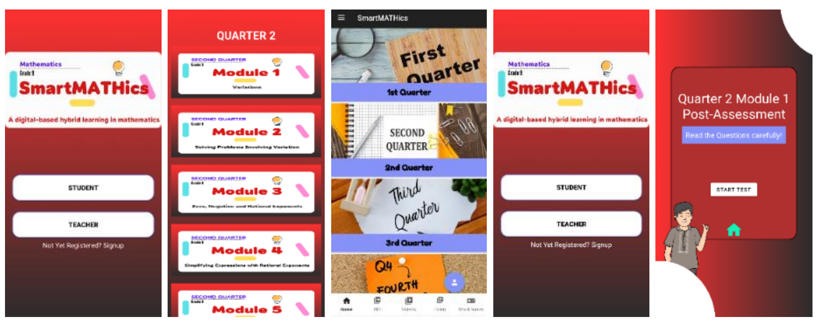

Figure 3. *Interface of Smartmathics*

3.2 Validity of Mobile Application "Smartmathics"

Table 2 illustrates the level of validity of Smartmathics, demonstrating a high level of validity in both content and technical aspects.

Table 2. *Level of Validity of Smartmathics*

Indicators	Numerical Rating	Interpretation
Content Validity	**5.0**	**Highly Valid**
Objectives	5.0	Highly Valid
Concepts	5.0	Highly Valid
Assessments	5.0	Highly Valid
Technical Validity	**5.0**	**Highly Valid**
UI/UX Design	5.0	Highly Valid
Hardware Interface	5.0	Highly Valid
Software Interface	5.0	Highly Valid
Overall Median	**5.0**	**Highly Valid**

The mobile application Smartmathics excels in both content and technical validity. Its content validity is evident through clear objectives that meet educational standards, fostering self-paced learning with flexible access to math materials and interactive digital resources that enhance engagement and create a blended learning environment.

The app ensures inclusivity by accommodating diverse learning needs and promoting digital literacy alongside mathematical skills, while its assessments align with objectives and encourage higher-order thinking. On the technical side, Smartmathics displays a visually appealing interface optimized for various devices, ensuring accessibility and usability with smooth functionality and user-friendly features. Thus, Smartmathics provides a highly valid platform for students to enhance their math skills in a flexible and engaging manner.

3.3 Acceptability of Mobile Application "Smartmathics"

Table 3 indicates Smartmathics is highly acceptable, attributed to its clarity, usefulness, language style, and illustrations.

Table 3. *Level of Acceptability of Smartmathics*

Indicators	Numerical Rating	Interpretation
Clarity	5.0	Highly Acceptable
Usefulness	5.0	Highly Acceptable
Language Style	5.0	Highly Acceptable
Illustrations	5.0	Highly Acceptable
Median	**5.0**	**Highly Acceptable**

Smartmathics garners high acceptance for its clarity, usefulness, language style, and illustrations. It employs a constructive and innovative approach, presenting information clearly and digestibly while sharing resources and references to ensure lesson reliability and relevance. Aligning with learners' needs and goals, Smartmathics offers accessible content that cultivates interest and understanding, featuring a clear and precise language style and illustrations that effectively depict concepts. Smartmathics emerges as a highly acceptable platform, facilitating engaging and compelling learning experiences for students.

3.4 Learners' Academic Performance Before and After Using "Smartmathics"

Table 4 outlines the pretest results for both the experimental and control groups, indicating that while the experimental group (Group 1) displayed a mean score of 15.00 and a standard deviation of 3.63, achieving a 30.00% mastery in mathematics, the control group (Group 2) achieved a mean score of 14.40 with a standard deviation of 3.22, resulting in a 28.80% mastery, suggesting both groups perform at a low mastery level.

Table 4. *Pretest Results of the Experimental and Control Groups*

Participants	Experimental Group Group 1	Control Group Group 2
Mean	15.0	14.1
StDev	3.63	3.22
% of Mastery	30.0%	28.8%
Descriptive Rating	Low Mastery	Low Mastery

The performance of the experimental group (Group 1) in the pretest was considered as low mastery. This could imply several factors influencing their performance, including differences in prior knowledge. It might also suggest areas of weakness in the curriculum or instructional methods that need to be addressed to enhance overall proficiency in mathematics within this group. Similarly, in the control group (Group 2), the overall performance remains at a low mastery level. Both groups' performance suggests a need for targeted interventions to enhance their mastery of mathematical concepts and skills. This might involve personalized learning approaches to address individual differences in learning needs and styles. Additionally, instructional strategies that promote engagement, critical thinking, and problem-solving skills could be beneficial.

Table 5 presents the posttest results of four groups, illustrating the impact of digital-based hybrid learning on mathematical performance. The experimental groups display notable improvements compared to the control groups, suggesting a positive trend toward mastery levels. In the Experimental Group (Group 1), a positive trend in academic performance was observed following the adoption of a digital-based hybrid learning approach. This implies that the teaching methods and resources used in the digital-based hybrid learning environment effectively supported students in improving their understanding and proficiency in Mathematics. Thus, the analysis suggests the potential efficacy of digital-based hybrid learning in enhancing learners' academic outcomes in mathematics. Group 2 achieved an average level of performance in mathematics through traditional teaching methods. There remains room for improvement, indicating that the traditional approach may not fully optimize students' mathematical potential. Thus, the average achievement, hinting at potential for further growth and enhancement beyond basic proficiency, highlighting the need for instructional strategies that can push students towards greater excellence in mathematics.

Table 5. *Posttest Results of the Four Groups of Participants*

Participants	Group 1 Experimental	Group 2 Control	Group 3 Experimental	Group 4 Control
Mean	41.1	29.9	37.3	28.3
StDev	4.04	5.62	4.77	5.54
% of Mastery	82.3%	59.9%	74.6%	56.7%
Descriptive Rating	Moving Towards Mastery	Average	Moving Towards Mastery	Average

Group 3 demonstrated significant achievement in mathematics despite not undergoing a pre-test. This validates the positive impact of this approach, suggesting that learners are making notable progress in understanding and skill development. This underscores the effectiveness of digital-based hybrid learning in enhancing academic performance, highlighting the benefits of integrating technology into the learning environment. The interactive and adaptive nature of this approach likely facilitated personalized instruction and active engagement, emphasizing the importance of leveraging technology to support students in their educational journey. For Group 4, the control group, which was exposed to traditional teaching methods without a pre-test, achieved an average post-test score, indicating a basic understanding of mathematical concepts. While demonstrating a foundational grasp of concepts, their performance fell short compared to other groups, suggesting that traditional methods may not fully capitalize on students' mathematical potential. This highlights the limitations of traditional teaching approaches in fully optimizing mathematical abilities, underscoring the need for continued exploration and refinement of teaching methodologies to unlock students' full potential in mathematics.

Table 6 compares the pretest scores of the experimental and control groups (Groups 1 and 2), revealing no significant difference despite slight variations in mean scores, as indicated by a p-value of .67, which exceeds the significance level of 0.05.

Table 6. *Z-test for Pretest of Experimental and Control Groups (Group 1 and Group 2)*

Pretest	Experimental Group Group 1	Control Group Group 2
Mean	15.0	14.4
Known Variance	13.1	10.3
Observations	30.0	30.0
z	0.67	
P(Z<=z) two-tail	0.49	
z Critical two-tail	1.95	

**0.05 level of significance*

The pre-test results of Group 1 showed a wider range of performance levels compared to those of Group 2. Both groups displayed relatively low levels of proficiency, indicating that many students lacked mastery of the assessed material prior to the intervention. These findings imply a need for targeted support and intervention strategies to improve academic performance across both groups. Despite differences in instructional approaches, both groups faced similar challenges in mastering mathematical concepts, highlighting the importance of addressing everyday educational needs. These results align with Gnanasagaran's (2019) findings, indicating comparable strengths in understanding among students regardless of group assignment.

Table 7 presents a comparison of the pretest and posttest results for the experimental group (Group 1), with a p-value of < .001, indicating a statistically significant difference in the learners' academic performance before and after using digital-based hybrid learning in mathematics. The experimental group, initially displaying low mastery levels in a pretest, underwent a significant transformation in their mathematical proficiency through digital-based hybrid learning. Post-test results showed a substantial increase in mean scores, indicating a remarkable advancement towards mastery level. This shift highlights the effectiveness of the hybrid approach in enhancing individual and collective proficiency, aligning with Murtiyasa's (2020) study, which found that the use of mobile learning media led to performance improvement. The flexibility and personalized experiences offered by this approach, as highlighted by Singh (2021) and Barman (2023), cater to diverse learning styles, empowering students to navigate their learning independently.

Table 7. *Z-test for Pretest and Posttest of Experimental Group (Group 1)*

Experimental Group Group 1	Pretest	Posttest
Mean	15.0	41.1
Known Variance	13.1	16.3
Observations	30.0	30.0
z	-21.3	
P(Z<=z) two-tail	0.00	
z Critical two-tail	1.95	

**0.05 level of significance*

Table 8 presents a comparison of the pretest and posttest results for the control group (Group 2). The p-value < .001 indicates a significant difference between the pretest and posttest of the control group, underscoring the potential of traditional teaching methods to foster meaningful learning experiences and outcomes.

Table 8. *Z-test for Pretest and Posttest of Control Group (Group 2)*

Control Group Group 2	Pretest	Posttest
Mean	14.4	29.9
Known Variance	10.3	31.5
Observations	30.0	30.0
z	-13.1	
P(Z<=z) two-tail	0.00	
z Critical two-tail	1.95	

**0.05 level of significance*

Group 2, the control group under traditional teaching methods, demonstrated a concerning level of mastery in the pretest. Following the traditional teaching approach, the post-test results showed a substantial increase in scores, indicating a notable enhancement in comprehension and skills, which transitioned to an average level of proficiency. This shift highlights the effectiveness of traditional methods, although further refinement is anticipated. While commendable, there is room for continued growth, highlighting the importance of exploring innovative pedagogical approaches and instructional techniques, as suggested by Mohammed (2021) and Darling (2021), to support diverse learners and promote deeper understanding and mastery in the classroom.

Table 9 presents a comparison of the post-test results for the four groups.

Table 9. *Post-Hoc Tukey HSD Test for Posttest of the Four Groups*

Treatment Pair	Tukey HSD Q Statistic	Tukey HSD p-value	Tukey HSD Inference
PostGroup1 vs PostGroup2	12.1	.001	Significant
PostGroup1 vs PostGroup3	4.17	.019	Significant
PostGroup1 vs PostGroup4	13.9	.001	Significant
PostGroup2 vs PostGroup3	8.01	.001	Significant
PostGroup2 vs PostGroup4	1.74	.596	Not Significant
PostGroup3 vs PostGroup4	9.75	.001	Significant

**0.05 level of significance;* $Q_{critical}$*=3.6866*

PostGroup1 vs PostGroup2. The experimental group (Group 1) exhibited significantly higher posttest scores compared to the control group (Group 2), indicating that digital-based hybrid learning fosters deeper understanding and mastery of math concepts through its interactive and personalized approach, suggesting its potential superiority over traditional methods. Group 1, exposed to digital-based hybrid learning, demonstrated significantly higher post-test performance compared to Group 2, which followed traditional teaching methods. This difference suggests that digital-based hybrid learning fosters deeper understanding and mastery of math concepts, likely due to its interactive and personalized nature, as observed in Türkmen's (2019) study. These findings underscore the potential of digital-based hybrid learning to revolutionize math education by creating dynamic, engaging environments that cater to diverse learning styles and maximize student engagement and achievement, aligning with Ede (2024) and Al-Abdullatif's (2021) research. The accessibility of this approach makes it a viable option for educators aiming to optimize student outcomes and prepare them for success in a technology-driven world.

PostGroup1 vs PostGroup3. The post-test of the experimental group (Group 1) highlights the impact of pretesting on student performance and underscores greater effectiveness of digital-based hybrid learning in mathematics than the experimental group (Group 3), with no pretest. Group 1, having undergone a pretest, demonstrated a higher posttest mean score compared to Group 3, which did not have a pretest. The presence of a pretest in Group 1 likely positively influenced their posttest outcomes by providing a baseline assessment, enabling targeted and personalized learning experiences. Despite lacking a pretest, Group 3 still showed significant progress in their posttest scores, indicating the effectiveness of digital-based hybrid learning in promoting student achievement. This suggests that regardless of the presence of a pretest, digital-based hybrid learning holds promise for enhancing students' understanding and proficiency in mathematics.

PostGroup1 vs PostGroup4. The posttest experimental group (Group 1) and control group (Group 4) reveal a significant difference in the efficacy of two distinct educational approaches. There is a significant disparity in the effectiveness of incorporating digital tools and hybrid learning techniques in mathematics education over the traditional approach. Group 1, having undergone a pretest, demonstrated a higher posttest mean score compared to Group 3, which did not have a pretest. The presence of a pretest in Group 1 likely positively influenced their posttest outcomes by providing a baseline assessment, enabling targeted and personalized learning experiences. Despite lacking a pretest, Group 3 still showed significant progress in their posttest scores, indicating the effectiveness of digital-based hybrid learning in promoting student achievement. This suggests that regardless of the presence of a pretest, digital-based hybrid learning holds promise for enhancing students' understanding and proficiency in mathematics.

PostGroup2 vs PostGroup3. The comparison between these two groups suggests that the digital-based hybrid learning approach employed by the experimental group (Group 3) was significantly more successful in fostering student learning outcomes compared to the traditional teaching approach used by the control group (Group 2). The traditional teaching approach, combined with a pretest, yielded moderate learning outcomes, suggesting limitations in its effectiveness without the addition of supplementary instructional strategies. In contrast, Group 3, utilizing digital-based hybrid learning without a pretest, demonstrated significantly higher post-test scores. This suggests that digital-based hybrid learning may inherently engage students more effectively, offering interactive resources and personalized experiences. The comparison suggests that the digital-based hybrid approach may better cater to diverse learning needs, offering flexibility and adaptability without the constraint of initial assessments, as supported by Lapitan (2021).

PostGroup2 vs PostGroup4. There is no significant difference in posttest scores between the two groups, which suggests that the inclusion of a pretest may have contributed to a slight advantage. The posttest results of Group 2 and Group 4 underscore the impact of pretesting on learning outcomes within a traditional teaching approach. While both groups achieved average mastery levels, Group 2, which underwent pretesting, displayed slightly higher posttest scores, highlighting the benefits of pretesting as a diagnostic tool to inform instructional practices and optimize learning experiences. The inclusion of a pretest likely enabled students to identify areas of strength and weakness beforehand, allowing teachers to tailor teaching strategies accordingly. These findings emphasize the importance of pretesting in enhancing the effectiveness of traditional teaching methods, personalize learning experiences, and target instructional interventions.

PostGroup3 vs PostGroup4. The posttest results indicate a significant difference between the two groups, affirming the superiority of the digital-based hybrid learning method over traditional teaching. Group 3 achieved notably higher post-test results compared to Group 4. This suggests a clear advantage in learning outcomes for Group 3, emphasizing the superiority of digital-based hybrid learning over traditional teaching methods. The significant difference in post-test scores underscores the effectiveness of incorporating digital tools and hybrid learning methodologies in enhancing student performance and comprehension in mathematics. These findings underscore the importance of integrating technology into teaching strategies to optimize learning experiences and outcomes, as emphasized by Pramesworo (2023). Moreover, digital-based hybrid learning holds promise in addressing diverse learning needs by offering interactive and adaptive learning experiences tailored to individual preferences and styles.

4.0 Conclusion

The development of SmartMathics, a mobile application designed to streamline digital-based hybrid learning in Mathematics, is aimed at enhancing both learning and teaching experiences, catering to the needs and preferences of digital-native students in today's technology-driven world. This underscores the potential of technology to address the needs of digital learners. Smartmathics' accurate and reliable educational content, coupled with its seamless technical execution, underscores its credibility and trustworthiness. It affirms the mobile application's effectiveness in facilitating meaningful learning experiences. SmartMathics garners widespread acceptance across multiple dimensions. It effectively meets the needs and expectations of its users, highlighting its value as a tool for enhancing the mathematical learning experience. The implementation of digital-based hybrid learning in Mathematics demonstrated a notable impact on student mastery levels compared to traditional methods. Thus, digital-based hybrid learning holds promise for enhancing student learning outcomes in Mathematics, highlighting its potential to bridge gaps in understanding and promote higher levels of proficiency. The introduction of digital-based hybrid learning in Mathematics has proven to be a transformative tool. The utilization of innovative technology underscores the immense potential of digital-based hybrid learning to revolutionize education, offering a dynamic and engaging platform that fosters deeper comprehension and higher achievement levels in Mathematics. Future studies could investigate the mobile application's effectiveness in various educational settings or assess its impact across different mathematics concepts. Additionally, some limitations were encountered during the study, such as the platform's accessibility and potential device compatibility issues, which future research could address to enhance its broader applicability and effectiveness.

5.0 Contributions of Authors

Orpilla, J. – editing, writing, encoding; Oredina, N. – data analysis, supervising

6.0 Funding

This research was conducted without external funding and is self-supported by the researchers.

7.0 Conflict of Interests

There is no conflict of interest.

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9.0 References

Al-Abdullatif, A. M., & Gameil, A. A. (2021). The Effect of Digital Technology Integration on Students' Academic Performance through Project-Based Learning in an E-Learning Environment. International Journal of Emerging Technologies in Learning, 16(11). https://doi.org/10.3991/ijet.v16i11.19421

Alkhateeb, M. A., & Al-Duwairi, A. M. (2019). The Effect of Using Mobile Applications (GeoGebra and Sketchpad) on the Students' Achievement. International Electronic Journal of Mathematics Education, 14(3), 523-533. https://doi.org/10.29333/iejme/5754

Barman, D., & Roy, S. K. (2023). The Transition from Offline to Online: Unveiling the Challenges and Opportunities. International Journal For Multidisciplinary Research, 5(4), 4444. https://doi.org/10.36948/ijfmr.2023.v05i04.4444

Braver, M. W., & Braver, S. L. (1988). Statistical treatment of the Solomon four-group design: A meta-analytic approach. Psychological Bulletin, 104(1), 150–154. https://doi.org/10.1037/0033-2909.104.1.150

Bringula, R., Reguyal, J.J., Tan, D.D. et al. (2021). Mathematics self-concept and challenges of learners in an online learning environment during COVID-19. Smart Learning Environments, 8(1), 22. https://doi.org/10.1186/s40561-021-00168-5

Creswell, J. W., & Creswell, J. D. (2017). Research design: Qualitative, quantitative, and mixed methods approaches. Sage publications.

Eden, C. A., Chisom, O. N., & Adeniyi, I. S. (2024). Harnessing technology integration in education: Strategies for enhancing learning outcomes and equity. World Journal of Advanced Engineering Technology and Sciences, 11(2), 001-008. https://doi.org/10.30574/wjaets.2024.11.2.0071

El-Sabagh, H. A. (2021). Adaptive e-learning environment based on learning styles and its impact on development students' engagement. International Journal of Educational Technology in Higher Education, 18(1), 53. https://doi.org/10.1186/s41239-021-00289-4

Gnanasagaran, D., & Amat, A. H. (2019). The effectiveness of mobile learning in the teaching and learning of probability. Jurnal Pendidikan Sains Dan Matematik Malaysia, 9(2), 9–15. https://doi.org/10.37134/jpsmm.vol9.2.2.2019

Kirisci, N., Sak, U., & Karabacak, F. (2020). The effectiveness of the selective problem solving model on students' mathematical creativity: A Solomon four-group research. Thinking Skills and Creativity, 38, 100719. https://doi.org/10.1016/j.tsc.2020.100719

Koole, M. (2009). A Model for Framing Mobile Learning. Retrieved from https://core.ac.uk/download/pdf/58775604.pdf

Linder, K.E. (2017). Fundamentals of Hybrid Teaching and Learning. Retrieved from https://doi.org/10.1002/tl.20222

Mufadhol, M., Siswanto, S., Susatyono, D. D., & Dewi, M. U. (2017). The Phenomenon of Research and Development Method in Research of Software Engineering, 1(1). https://doi.org/10.29099/ijair.v1i1.4

Murtiyasa, B., Jannah, I. M., & Rejeki, S. (2020). Designing mathematics learning media based on mobile learning for ten graders of vocational high school. Universal Journal of Educational Research, 8(11), 5637-5647. https://doi.org/10.13189/ujer.2020.081168

Papadakis, S., Kalogiannakis, M., & Zaranis, N. (2021). Teaching mathematics with mobile devices and the Realistic Mathematical Education (RME) approach in kindergarten. Advances in Mobile Learning Educational Research, 1(1), 5-18. https://doi.org/10.25082/AMLER.2021.01.002

Pramesworo, I. S., Sembiring, D., Sarip, M., Lolang, E., & Fathurrochman, I. (2023). Identification of New Approaches to Information Technology-Based Teaching for Successful Teaching of Millennial Generation Entering 21st Century Education. Jurnal Iqra': Kajian Ilmu Pendidikan, 8(1), 350-370. https://doi.org/10.25217/ji.v8i1.2722
Sharples, M., Taylor, J., & Vavoula, G. (2005, October). Towards a theory of mobile learning. In Proceedings of mLearn, 1(1), 1-9.
Singh, J., Steele, K., & Singh, L. (2021). Combining the best of online and face-to-face learning: Hybrid and blended learning approach for COVID-19, post vaccine, & post-pandemic world. Journal of Educational Technology Systems, 50(2), 140-171. https://doi.org/10.1177/00472395211047865
Swope-Farr, T. (2021). Examining virtual mathematics instruction: A comparative case study of in-service elementary teachers with mathematics anxiety and mathematics teaching self-efficacy (Order No. 28498977).
Teisan, J. L. (2018). At Home with Science: A Qualitative Study of Science Teaching in Homeschools (Doctoral dissertation). Oakland University